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1. Contractors Name and Address .

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PROGRESS REPORT NO. 6

Project Title: "Measurement of Damping of Graphite Epoxy Material"

Sponsor: NASA George C. Marshall Space Flight Center,  
Huntsville, AL 35812

Period: March 1, 1985 - March 31, 1985

The work performed during the above period was concerned with the measurement of the damping of the cylindrical specimen and the thin plate graphite epoxy specimen using the forced vibration test methods. Special efforts were made to measure the material damping of the composite specimens. The idea was to minimize the contribution of the specimen edge supports to the total damping value measured. As reported in the earlier progress reports, it was observed that the specimen end supports contributed significantly to the damping value measured on the specimen.

The experiments were first performed on the cylindrical graphite epoxy specimen. The specimen was tested using the following edge support conditions, (i) three point support (ii) knife edge support to simulate an idealized simply supported boundary condition. The edge supports were the same as those used on the specimen during the free-vibration tests reported earlier. A schematic diagram of the experimental set-up is shown in Figure 1. The specimen was excited by means of an exciter driven by a random noise generator. The frequency response of the specimen in the form of its mobility function (velocity/force) was measured using an impedance head and the dual

channel signal analyzer (B & K 2032). From the response curve the half power points and hence their bandwidth of frequency separation ( $\Delta f$ ) and the natural frequency ( $f_n$ ) of the specimen were measured. The damping ratio ( $\zeta$ ) is given by

$$\zeta = \frac{\Delta f}{2f_n}$$

Figure 2 shows one of the frequency response curves (mobility vs frequency) obtained for the specimen with the three point support. The experiment was repeated for four times (on different days) and an average value of the damping ratio for the composite cylindrical tube with the three point support was obtained to be of the order of 1.15 %.

Using the same experimental setup, a second set of experiments was conducted on the cylindrical tube specimen with the ends supported by means of knife edges in order to simulate a simply supported boundary condition. In this case also, the measurements were repeated several times in order to check their repeatability and consistency. Figure 3 shows one of the frequency response curves of the composite tube with the knife edge supports. The damping ratio value obtained in this case using the half power point method was of the order of 0.57%. The difference in the damping ratio of the composite specimen with the two edge support conditions confirms our earlier statement that the edge supports had a lot of influence on the damping ratio of the specimen.

However, in order to further investigate the influence of the supports at the two ends of the composite tube specimen, a

third set of experiments was conducted. In this experiment the composite tube was held in the air by suspending the tube by means of two rubber ropes, one at each end of the tube. The tube was excited by means of an electrodynamic shaker through an impedance head. In all of the above tests a circular ring having an inside circular knife edge was mounted in the middle of the tube. The inner knife edge of the ring allowed the tube to be held firmly in the ring. The impedance head was then connected to the hole on the outer surface of the ring. The schematic diagram of the experimental set-up is shown in Figure 4. The damping ratio value obtained in this set of experiments was of the order of 1.8%. A comparison of this value of the damping ratio of the composite tube with the values obtained by the other two methods suggests that the damping measured in this method has a significant contribution from the rubber ropes used for suspending the tube.

Having established that the damping ratio of the composite tube is strongly dependent on the end support conditions, it was decided to support the specimen so that the two ends of the tube are not constrained at all. This type of support simulated an idealized free-free boundary condition at the two edges. A schematic diagram of the experimental set-up is shown in Figure 5. The specimen was carefully mounted directly on the shaker through the supporting ring and the impedance head. The damping ratio value of the specimen which was measured was about 0.13%. The damping ratio value obtained in this experiment is believed to be mostly due to the material damping of the specimen as there

were no structural joints and the specimen was not constrained at its ends. The measurements were repeated several times and on different days, in order to check the consistency of the result. Similar results were obtained on all these occasions. The experiment was also repeated with two other types of excitation signals, 1) pseudo random noise and 2) variable sine with manual sweep - the same result was obtained with both these types of excitation.

Further work is in progress in this direction to calculate the damping induced by the supporting ring used in the previous experiments. This would enable us to refine the damping results further. Furthermore, a curve fitting technique is being used to process the frequency response data obtained with these composite specimens. This would then give a better resolution of the frequency bandwidth at resonance required in the half power point method and thus the estimated damping ratio would be more accurate than the result obtained by considering just the three points at and near the resonance frequency. It is also proposed to estimate the damping ratio by using other methods like 1) Kennedy-Pancu Method and 2) Power Input Method.

Some experiments were conducted on the thin plate composite specimen recently sent by NASA. Here also it has been observed that the end support conditions have a strong influence on the damping ratio of the specimen. The thin plate specimen was clamped at one end and held free at the other, as a cantilever beam. Damping was measured using free and forced vibration tests. The damping ratio value obtained was between 2.1 - 2.5%.

The same beam was later mounted on the shaker through an impedance head. The two ends of the beam were not constrained with any supports to simulate a free-free boundary condition. The damping ratio value measured in this case was of the order of 0.56%. Comparing this value of the damping ratio with the value of 0.13% obtained for the cylindrical tube specimen which was also held as a free-free beam, it can be concluded that the damping ratio value measured is also strongly influenced by the shape of the specimen. It is also believed that the damping ratio of the composite specimen depends on the length and orientation of the fibers and the presence of discontinuities such as sharp bends, corners and notches. Further experiments need to be conducted to study the influence of the above factors.

It is also proposed to measure the damping ratio of the NASA (6 ft) tube using the forced vibration test methods. Earlier measurements were made on this specimen using the free vibration test methods. We are working with the NASA personnel in order to fix a suitable date convenient for both the groups to conduct these experiments at Auburn.

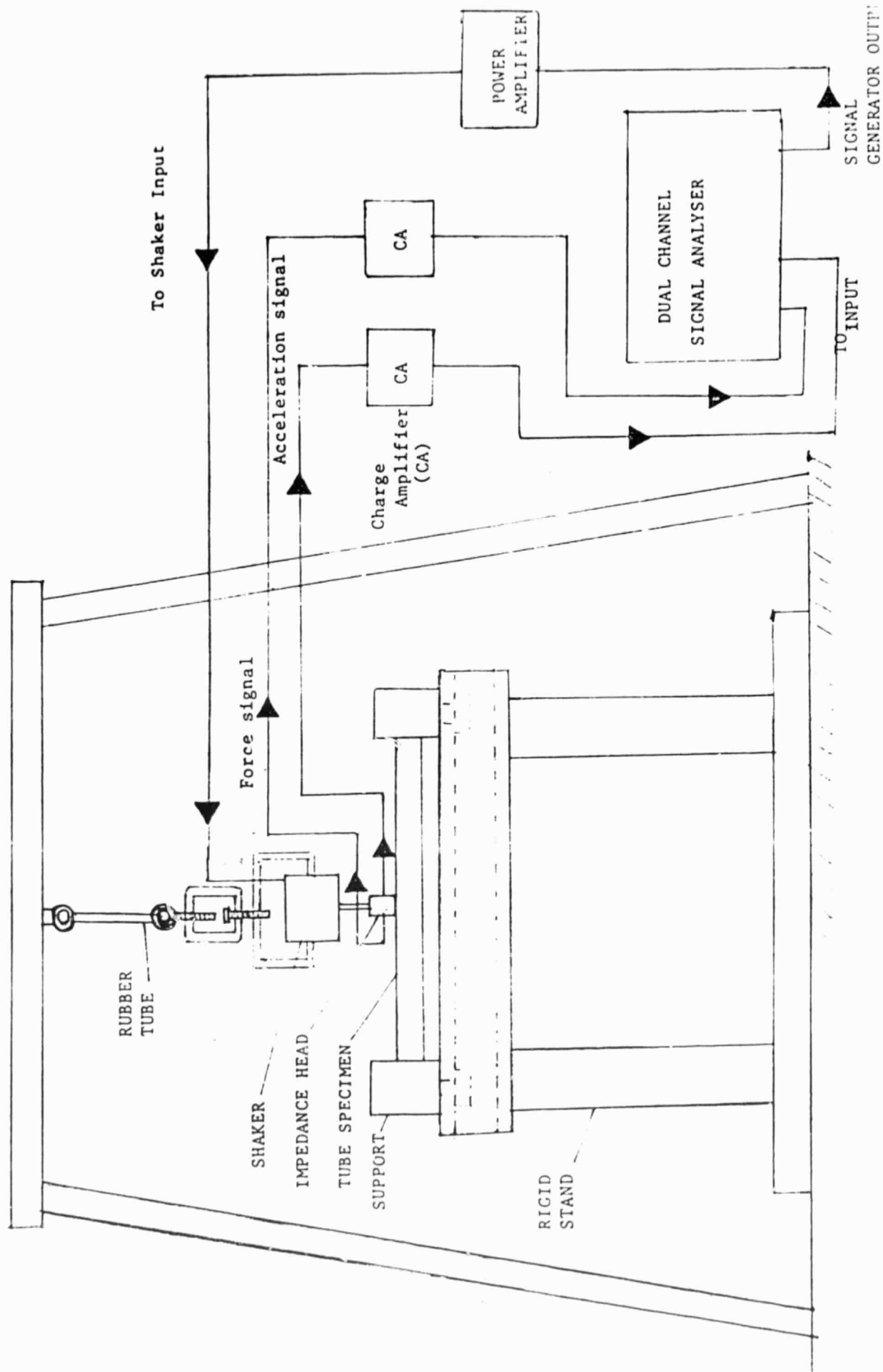


Figure 1. EXPERIMENTAL SET UP FOR FORCED VIBRATION TEST



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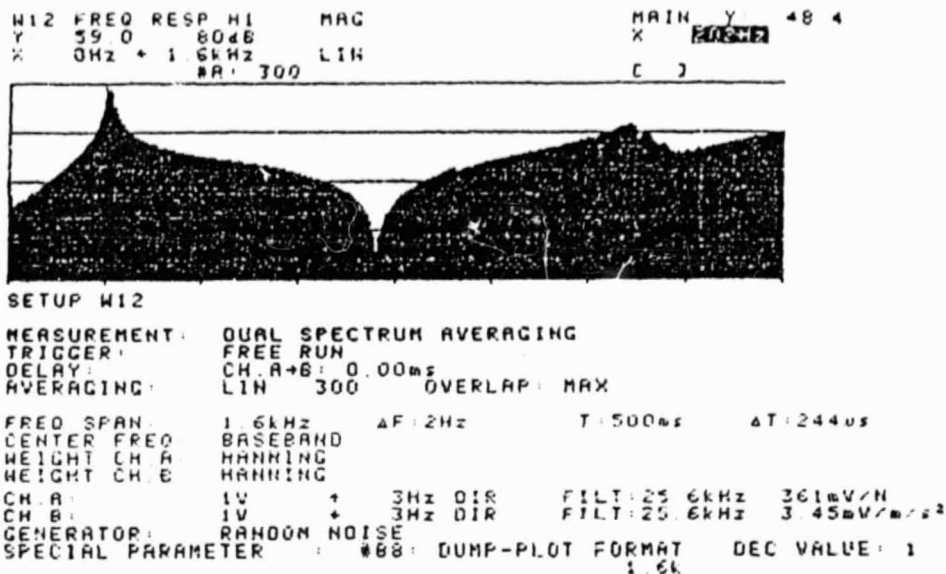


Figure 2. Frequency Response curve with 3-point support.

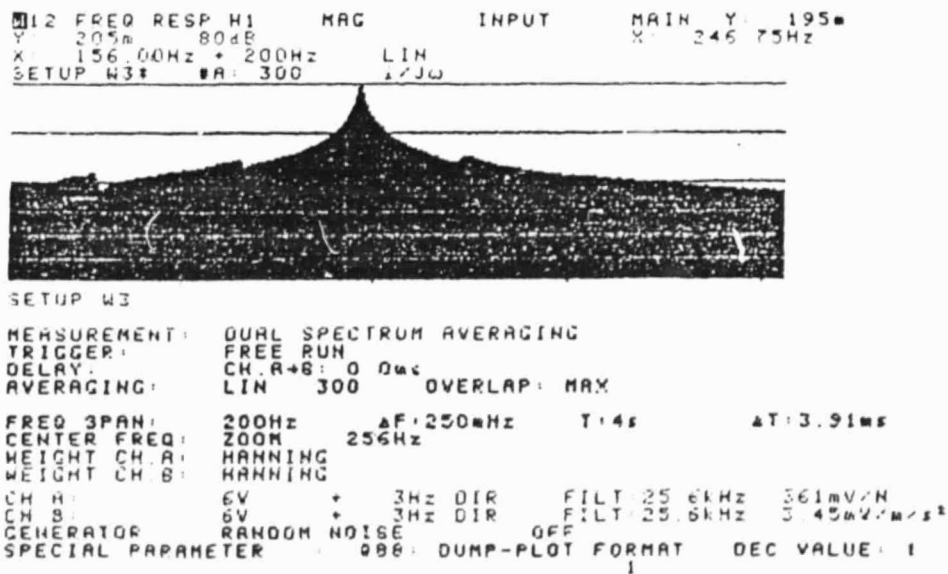


Figure 3. Frequency Response curve with knife edge boundary condition.

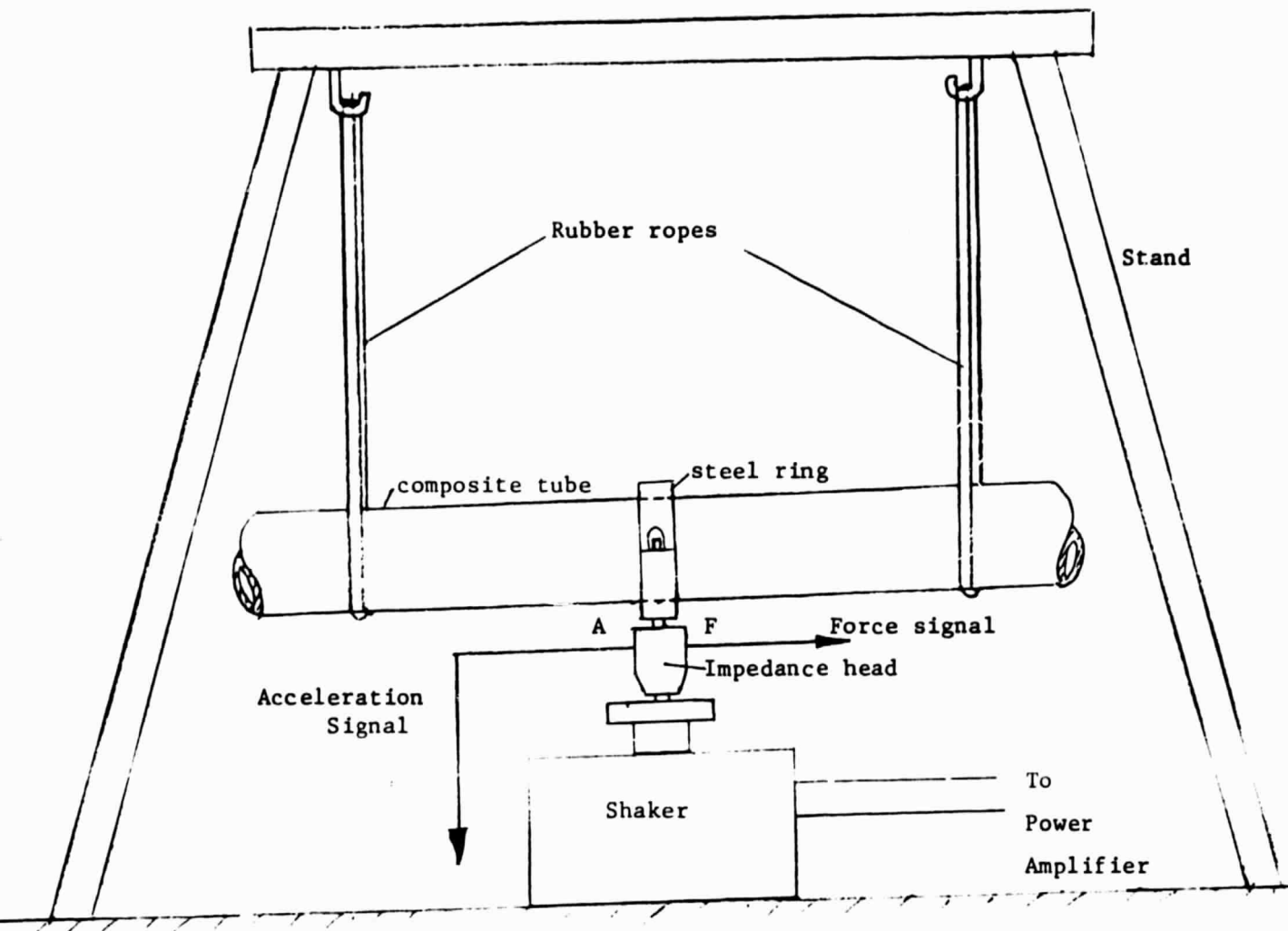


Figure 4. Experimental set up for forced vibration. (with rubber ropes)

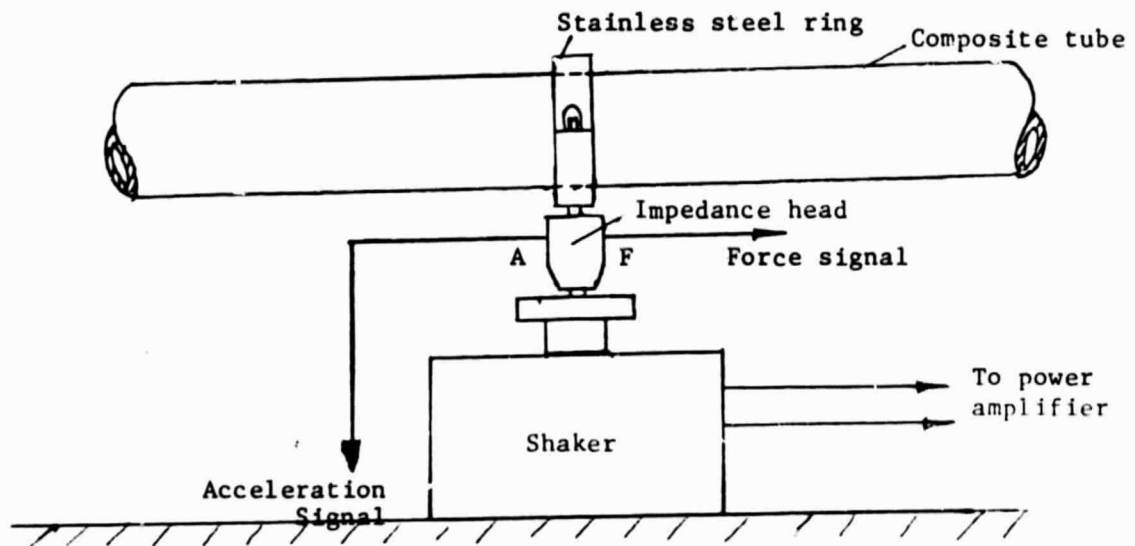


Figure 5. Experimental set up with Free-Free boundary condition.

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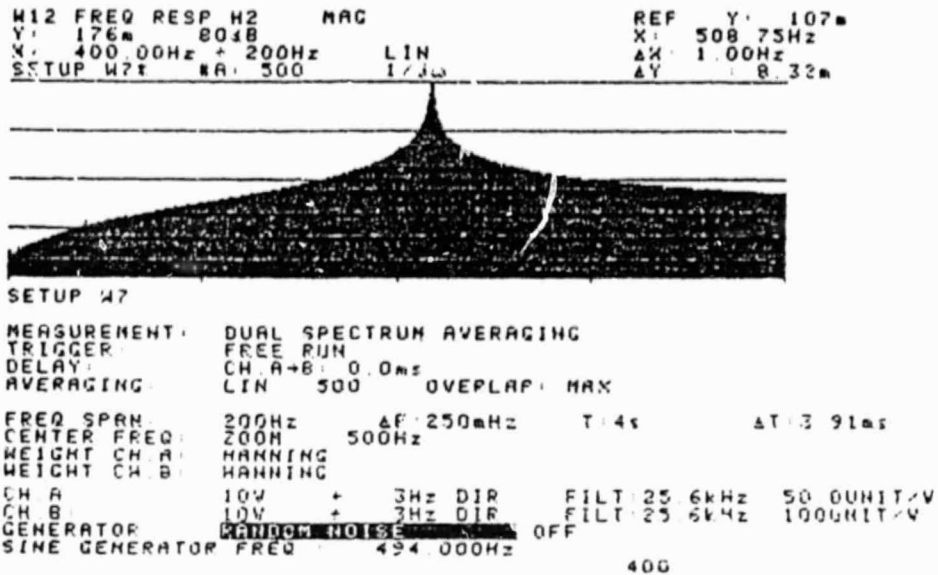


Figure 6. Frequency response curve with Free-Free boundary condition.